ON-TIME Final Event, Genoa, 28 October 2014

[Optimal Networks for Train Integration Management across Europe]
Collaborative Project
7th Framework Programme

WP3 Development of robust and resilient timetables
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WP3 Development of robust and resilient timetables

- Introduction
- Timetable performance indicators
- Timetabling approach
- Demonstration multilayer timetable
- Computation times
- Infrastructure occupation
- Quantitative evaluation
- Conclusions
Introduction

WP3
- Development of robust and resilient timetables

Innovation 2
- The development of improved methods for timetable construction that are robust to statistical variations and resilient to perturbations in operations
Introduction

Stations, signals

Time
Introduction

<table>
<thead>
<tr>
<th>Time</th>
<th>Distance</th>
</tr>
</thead>
</table>

- Graph showing the relationship between time and distance.
Performance indicators

Timetable trade-off between performance measures

- Short travel times
- Seamless connections
- Realisability
- Conflict-freeness
- Stability: acceptable capacity occupation in corridors and stations
- Robustness
- Resilience
- Residual capacity for freight paths
- Energy efficiency
Timetabling approach

• Microscopic (track section level)
  – Speed and running time computations incl. time supplements
  – Conflict detection using blocking times
  – Infrastructure occupation & stability tests by compression method
  – Accuracy 1 s

• Macroscopic (network level)
  – Network timetable optimization of travel, transfer and settling times
  – Stochastic robustness analysis using Monte Carlo simulation
  – Timetable precision of 5 s minimizing capacity waste

• Fine-tuning (corridor level)
  – Stochastic optimization of stops using dynamic programming
  – Energy-efficient speed profiles using optimal control

• Standardized RailML data exchange
Timetabling approach

**MACROSCOPIC**
- Robustness Evaluation
- Macro Timetable Optimization

**MICROSCOPIC**
- Minimum Running Time Computation
- Operational Running Time Computation
- Minimum Headway Computation

**FINE TUNING**
- Energy Efficient Trajectory Computation
- Bandwidth Estimation
- Corridor Timetable Optimization
- Energy-efficient Timetable
- RAILML Writer
- RAILML Timetable

**Other Timetable Parameters**
- Turn-around times
- Minimum dwell times

**RailML Converter**
- Rail ML Data
  - Infrastructure
  - Rolling Stock
  - Interlocking
  - Signalling / AP
  - Routes

**Microscopic Data**
Dutch case study

- Infrastructure and line plan 2012
- Two intersecting corridors
  - Utrecht-Eindhoven and
  - Tilburg-Nijmegen
- Hourly timetable pattern with
  - 2 x 8 ICs per hr
  - 2 x 10 local trains per hr
  - One freight path (Ut-Ehv)
  - Many transfers in ‘s Hertogenbosch (and elsewhere)
Demonstration

Model sizes

- Microscopic network
  - 1500 nodes
- Block section level
  - 1000 nodes
- Macroscopic network
  - 16 nodes
Blocking time diagram for route of train line 3500

Time [min]

Distance [stations]

Ut Utl Htn Cl Gdm Zbm Ht Vg Btl Bet Ehv

Fast freight path
Freight path

- 120 km/h

- 80 km/h
Computation times

Number of conflicting train paths vs. Number of iterations

- Solid line: Number of conflicting train paths
- Dashed line: Sum of all conflict times [s]
## Computation times

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<thead>
<tr>
<th></th>
<th>Iterations</th>
<th>Mean time [s]</th>
<th>Total [s]</th>
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<tr>
<td><strong>Micro-macro iterations</strong></td>
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<td>Macro (1000 macro iterations)</td>
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<td>Micro computations</td>
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<td><strong>Finetuning</strong></td>
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<td>Energy-efficient speed profiles</td>
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<td><strong>Total</strong></td>
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*Excluding stochastic optimization of local trains
Infrastrucure occupation

Track-free detection sections Nijmegen - 's Hertogenbosch
Station infra occupation

Infrastructure occupation Geldermalsen

Time [s]

Track-free detection section
Station infra occupation

Scenario 1
Scenario 2
Scenario 3
## Quantitative evaluation

<table>
<thead>
<tr>
<th>JT</th>
<th>O-D</th>
<th>Ref.</th>
<th>Scenario 1</th>
<th>Scenario 2</th>
<th>Scenario 3</th>
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<tbody>
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<td>Mean journey time [min]</td>
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<td>Ut-Ehv</td>
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<td>O-C–D</td>
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<td></td>
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<tr>
<td></td>
<td>Mean transfer time [min]</td>
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<td>Reference</td>
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<td>%</td>
<td>kWh</td>
<td>%</td>
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### Quantitative Evaluation

<table>
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<tr>
<th>RS Station</th>
<th>Delay difference Baseline – Reference</th>
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<td>Sum [s]</td>
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<tr>
<td>'s Hertogenbosch</td>
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<tr>
<td>Eindhoven</td>
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<td>Utrecht Centraal</td>
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<td>Tilburg</td>
<td>2292</td>
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<tr>
<td>Nijmegen</td>
<td>1510</td>
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Conclusions

- Modular implementation of three-level timetabling approach
- Standardized RailML files (Infrastructure, Rolling Stock, Interlocking, Timetable)
- Output in standardized RailML Timetable file with scheduled train paths and speed profiles at section level
- Multilayer timetable with multispeed freight path catalogue
- Classification of Timetabling Design Levels
  - TDL 0: Low quality
  - TDL 1: Stable
  - TDL 2: Conflict-free (and stable)
  - TDL 3: Robust (and conflict-free and stable)
  - TDL 4: Resilient (proof that a robust conflict-free timetables exists and can be derived dynamically fast w.r.t. freight and delays)